

**TESTIMONY OF**  
**MARK A. SHANNON**  
**DIRECTOR**  
**CENTER OF ADVANCED MATERIALS FOR THE PURIFICATION OF WATER**  
**WITH SYSTEM SYSTEMS (*WaterCAMPWS*)**  
**University of Illinois at Urbana-Champaign, Urbana, Illinois 61801**  
**BEFORE THE ENVIRONMENT AND PUBLIC WORKS COMMITTEE**  
**UNITED STATES SENATE: WATER AND WILDLIFE SUBCOMMITTEE**

March 31, 2009

Good morning Chairman Cardin, Ranking Member Crapo, and distinguished members of the Water and Wildlife Subcommittee. I want to thank you for the opportunity to testify before the Subcommittee today. I especially want to thank Chairman Cardin for his leadership on this issue, which is critical to the public health and economic prosperity of our Nation. I am Mark Shannon, Director of the Center of Advanced Materials for the Purification of Water with Systems, a National Science Foundation Science and Technology Center headquartered at the University of Illinois at Urbana-Champaign. This Center focuses on finding solutions to the coming water crisis through revolutionary advances in science and technology. We partner with major stakeholders in the water sector through an Industrial Affiliates program of companies across the U.S.<sup>1</sup> I am also the Co-Founder of the United States Strategic Water Initiative, which is a consortium of companies, academic researchers, and water associations acting together to advance the science of water purification and to accelerate delivery of new U.S. technologies necessary to increase and protect fresh water supplies, including different types of sourcewaters that are not now readily usable.<sup>2</sup> In particular we seek increase the chemical and energy

---

<sup>1</sup> Industrial Affiliates and Partners: Archer Daniels Midland (ADM), Applied Membrane Technologies (AMT), Biolabs/Chemtura, Clorox-Brita, Cargill, Culligan, Damon S. Williams Associates (DSWA), ITT, Metropolitan Water Reclamation District of Greater Chicago, Pentair, Porex Porous Products, PPG, Praxair, Siemens, UOP/Honeywell, Water and Wastewater Equipment Manufacturers Association (WWEMA).

<sup>2</sup> List of signers: Ken Kirk - National Association of Clean Water Agencies; Mark Shannon, Jian-Ku Shang, Michael Plewa, Eberhard Morgenroth, Timm Strathmann, Richard Sustich - *WaterCAMPWS*/University of Illinois at Urbana-Champaign; Kofi

efficient use of water, and to create new methods to conserve, desalinate, reuse, decontaminate, and disinfect waters. By doing so, we will be able increase the amount of available water to meet the future needs of our country and world, without needing to transport fresh waters over long distances at huge costs in capital and energy usage.

I appreciate this opportunity to provide input to the Committee on the issues of water use efficiency and conservation, particularly with respect to critical research the Environmental Protection Agency will need to address. I believe strongly that research and development (R&D) into new water technologies can lead to new opportunities for U.S. companies, providing good jobs for Americans, while solving our water problems. It is my opinion that legislation is needed to enhance the United States R&D, demonstration, education, and technology transfer efforts in water technologies. In particular, I would like to talk about needs for new research in water use efficiency and conservation conducted by and for the Environmental Protection Agency.

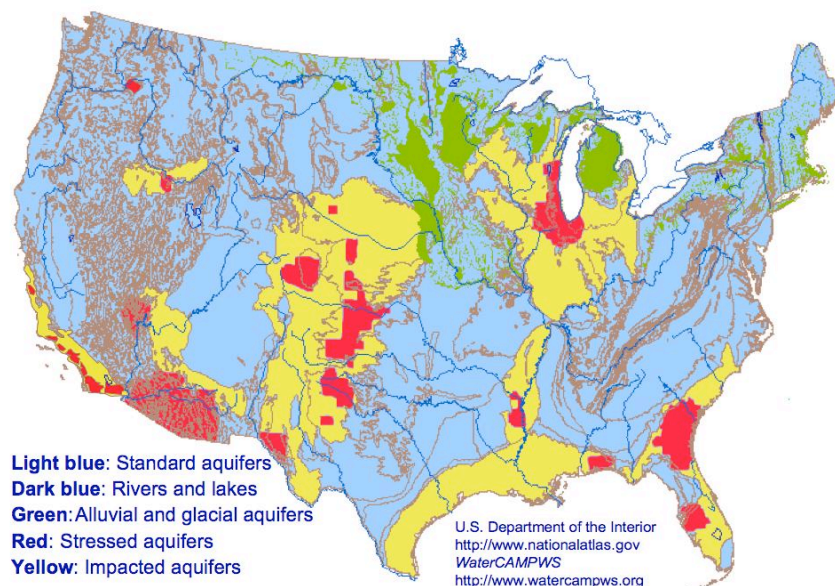
#### Water Availability Issues

A key driver for efficient water use and conservation is the ongoing reduction in clean water available from our lakes, rivers, and ground water aquifers (our largest source of fresh water for human use). As shown in the U.S. map of aquifers, regions shown in red have reported rapidly dropping aquifers. For instance, regions of the High Plains Aquifer in New Mexico and Texas experienced water level declines of more than 60 feet between 1980 and 1999. As aquifers are drawn down to great depths, the water becomes saltier, since saltwater is heavier than fresh. Some wells around the U.S. are so deep that the waters are becoming brackish, and

---

Bota, Eric Mintz - *WaterCAMPWS*/Clark Atlanta University; Rishi Shukla - Archer Daniels Midland; Greg Pepping - University of Wisconsin; David Henderson - XPV Capital Corporation; Richard White - Lawrence Livermore National Laboratory; Shaurya Prakash - Rutgers University; Lutgarde Raskin - University of Michigan; Slav Hermanowicz - University of California at Berkeley; Tanna Borrell - University of Michigan; Scott Husson - Clemson University; Eva Steinle-Darling - Stanford University; Wen-Tso Liu - National University of Singapore; Daniel Brunelle - GE Global Research; Mark Rigali - Sandia National Laboratories; Darren Sun - Nanyang Technical University; Franz Hoffman – Procorp Enterprises, Milwaukee.

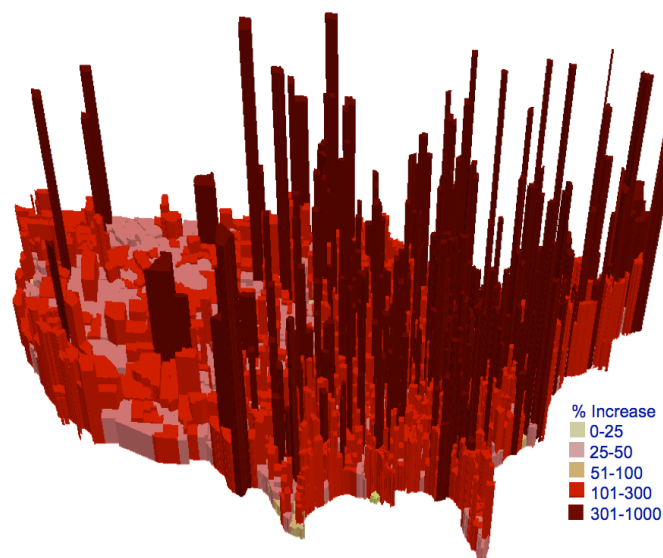
need desalinating before they can be used. Also, along the oceans and bays, saltwater is drawn into aquifers that are drawn down, making them brackish too, which is a growing problem along the Gulf Coast, and southern Atlantic and Pacific coasts. Salting of rivers and lakes is also occurring from land runoff and chemical use by every sector in the U.S. Thus, the U.S. is losing available fresh water by salting. If we add in periodic droughts across the U.S. that dramatically increase the drawdown of aquifers, and the loss of storage of water in the snowpack of the western mountain ranges, critical shortages in available water will become more frequent and severe. Recent reports of the declining water level in Lake Mead suggest that if it continues, within a decade the level may drop below the intakes. If this happens, water supplies will be dramatically cut for 30 million residents in southern Nevada, Arizona, and California. It is vital to have in place before it happens ways to mitigate shortages and to increase available supplies for all regions of the U.S. While there are regional efforts to look at water availability, national legislation is needed to address the growing number of critical issues with water availability.



A U.S. Map of all rivers, lakes, standard and “fossil” groundwater aquifers, which waters deposited thousands of years ago, and are slowly replenished if at all. Over-pumping can stress aquifers, and can impact water supplies. Estimates are shown of stressed (red) and impacted (yellow) aquifers throughout the U.S. More data is needed to know the rates of depletion and recharge of the sourcewaters.

At the same time that water supplies are decreasing, growth in population, energy use, and hopefully economic expansion, will drive demand for more water use. Local water demand will vary throughout the U.S., with many areas likely to experience very high growth rates, as shown below of the local projections in percentage increase in water use by 2030 over that used in 2000. Finding that water will be difficult and very expensive for conventional sources of water, since all the all the easy, low-cost water has already been developed. Therefore new ways to extend current sources of water are needed, as well as low-cost ways to expand water supplies.

While the projections show large increases throughout the U.S. if we do not change our water use practices, the good news is that large increases in potable and non-potable fresh water supplies can be realized by reusing existing wastewater, and desalinating brackish and saline sources (lakes and deep



Predictions of increase in local water use by 2030, as a percentage increase over year 2000. Note that percentage increase does not reflect the total local increase, as increases in southern California are greater at 101 to 300% than Denver at 301 to 1000%. However, percentage increases do reflect the need of local systems to increase water supplies.

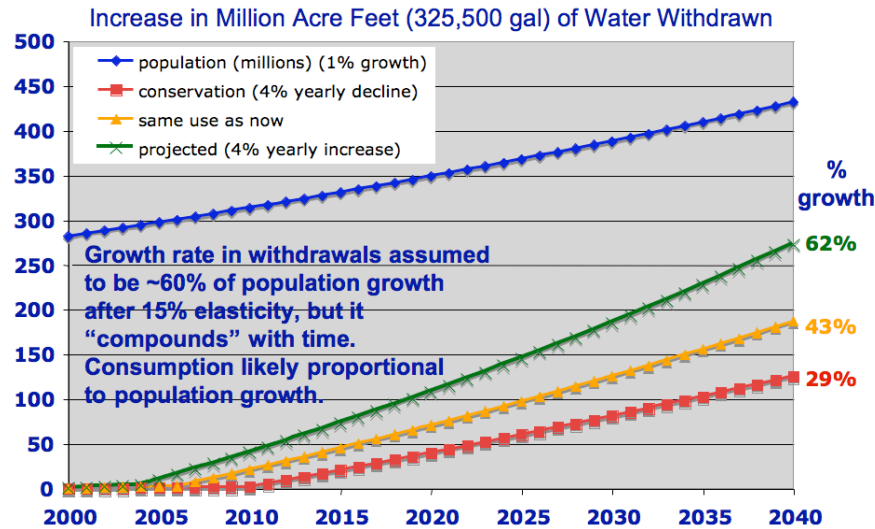
Population data and projections from U.S. Census Bureau (<http://www.census.gov/population/www/projections/stproj.html>, <http://www.census.gov/popest/datasets.html>). Water Use Data from USGS (<http://web1.er.usgs.gov/NAWQAMapTheme/index.jsp>). Water use based on Texas Water Use 60 Year Projections ([http://www.twdb.state.tx.us/publications/reports/State\\_Water\\_Plan/2007/2007StateWaterPlan/2007StateWaterPlan.htm](http://www.twdb.state.tx.us/publications/reports/State_Water_Plan/2007/2007StateWaterPlan/2007StateWaterPlan.htm))

aquifers that exist almost everywhere in the U.S.). Perhaps surprisingly, our best technologies today are far from being limited by the natural laws of physics and chemistry. But in biological systems, salts and contaminants are removed from water very close to the natural limits. Thus, it *is possible*, in spite of common opinion, to dramatically cut the use of energy and chemicals in desalination and reuse technologies. Energy efficient desalination of saline and impaired waters that currently are not used as sourcewaters, as well as desalination of seawater along the coastlines, can have a profound impact on increasing available water supplies. Therefore, legislation that can help accelerate the development of low-energy desalination methods is timely and needed.

***Critical research needs that can be supported through the EPA to enhance water availability includes:*** (i) low-energy use desalination technologies below that possible by state-of-the-art reverse osmosis methods, including combined energy and water generation systems, (ii) reduction of the brine leftover from desalination to near zero to allow efficient inland desalination and zero discharge of brine along coastlines, (iii) recovery of valuable minerals from the concentrated brine resulting from desalination seawater and saline aquifers, and (iv) investigation of compounds in desalinated and reused waters to ensure safety of the new water supplies.

### Water Conservation and Reuse

In order to meet the water needs of Americans, we need new ways to conserve water to dramatically reduce consumption. With a projected U.S. population growth of over 100 million people within 30 years and the growth in consumption patterns with respect to domestic, industrial, agricultural, and energy usage, the U.S. will need to increase total water supplies by up to 62 percent using current technologies and practices, as shown in the figure below. Even if we are able to restrict per capita consumption to 2000 levels, we will need up to a 43% increase



The average overall increase in population of the United States is shown in blue, assuming a 1% (between the low and high estimates). Three estimates for the growth in water supplies needed to sustain the population growth, assuming a projected increase in per capita consumption to account for higher use of energy and economic expansion (in green) of 62% by 2040 (using current technologies), use at current levels (in orange) of 43%, and a drop in per capita use of 4% per annum from increased conservation and efficiency (in red) of 29%. The conservation projection requires by 2040 60% less in domestic use, 30% less for energy production, and 20% for agriculture and livestock, which requires new technologies.

Population Data from US Census Bureau: Lowest estimate at 0.9% per annum through to 2030

The Blueprint 2030 forecast of the revised United States population growth from 2000 to 2030 was 1.14%

in water supply capacity by 2040. But with conservation, we can cut in half the demand for new water supplies. Lots of technologies from low-flow showerheads and toilets exist, but none that can reduce water use by an average of 4% per year every year for the next 3 decades. To achieve that reduction, domestic use would have to decline by 60%, energy use by 30%, and agriculture by 20% per capita. But conservation via improved efficiencies and reduction in wastewaters can reduce the costs of clean water, increase the standard of living, and halve projected consumption.

Perhaps the single largest conservation opportunity is through reuse. Currently, in most of the U.S. we treat all water to the highest possible standard – drinking water. However, most of our uses do not need to meet the quality of human health. Uses such as flushing toilets, cooling water for air conditioning, laundry, irrigation, and washing autos, etc. comprise much of the use. Technologies exist today that can reclaim wastewaters and make them safe for non-potable uses.

Where these systems have been installed, water use has dropped by some 50%, without any decline in the standard of living. Moreover, the amount of wastewater discharged also declines, improving the environment. With new research, an even higher percentage of water (80% or higher) can be recovered, creating even more conservation at lower cost and a higher standard of living. In addition, new technologies can be created to recover the energy that wastewater contains, so that less energy is used in the water treatment. Less water discharged, pumped, and treated for both supply and waste means far less energy needs to be spent on treating and pumping water. Currently ~10% of all the oil energy we import every year is used to treat and pump water. Thus, conserving water through reuse can also dramatically reduce energy consumption. Finally, the nutrients that are found in wastewater can also potentially be recovered when reusing water, and made into fertilizer. New research to recover water, energy, and nutrients from wastewater can dramatically increase our ability to conserve these resources.

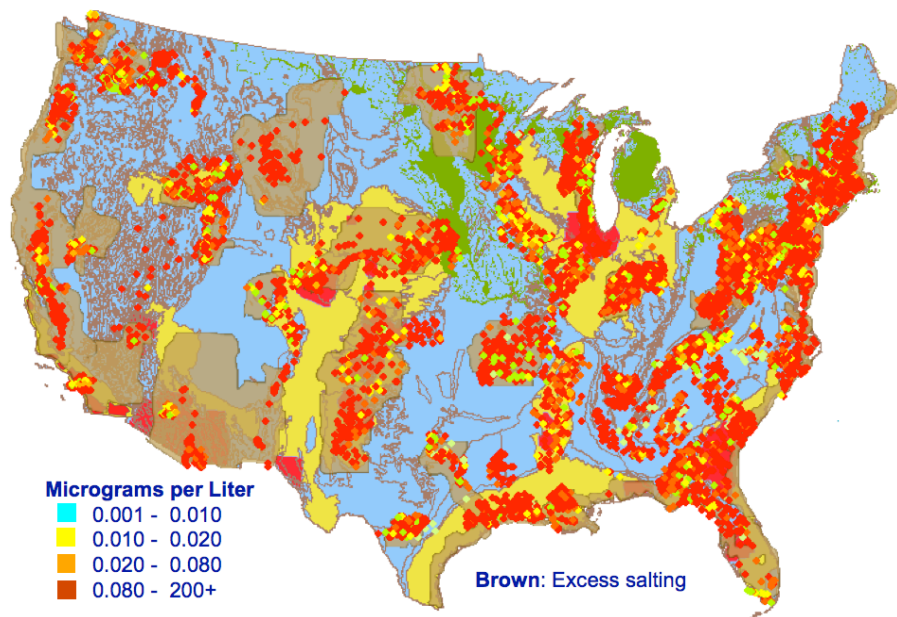
***Critical research needs include:*** (i) assessment of interactions between different water use sectors (agriculture, livestock, mining, energy, domestic, and industry) on water use, conservation, and reuse, (ii) understanding the environmental impact of changing withdrawal, consumption, and discharge patterns on overall water systems, (iii) establishment of standards for potable and non-potable waters derived from these sources to maintain a safe water system, (iv) development of new technologies to reuse water from single user to large scale systems, with low-cost technologies for retrofitting buildings to use non-potable waters, and (v) development of energy and nutrient recovery reuse technologies.

#### Contaminant and Pathogen Detection, Decontamination and Removal

In the U.S., we have historically achieved water safety by brute force. We find a clean water source, often transport it long distances, treat it with chemicals, and pump it up to high pressure,

and then distribute it in large systems. Significant amounts of water are lost in transporting, treating, and distributing it. Evaporation in open transport channels and leakage from high-pressure distribution systems cause huge loss of water. With an aging and crumbling distribution infrastructure that has over 250,000 water *main* breaks a year, the U.S. loses a huge amount of water. Repairing and building new infrastructure to increase water efficiency is likely to cost hundreds of billions of dollars. AWWA estimates each American owes nearly \$500 for infrastructure repair to our current system. Using new technologies to prevent leakage is an important step in stopping leakage losses, but it is expensive to retrofit the entire distribution system.

In addition to leakage losses, a new disturbing trend is the contamination of sourcewaters with pollutants that are difficult to remove even in centralized systems, such as pharmaceutical compounds and plasticizers. Toxic byproducts that occur during water treatment itself, such as disinfection, also are appearing in larger amounts in our water systems. As shown in the figure



Map of the aquifers of the United States, with the EPA's Critical Drinking Water Pollutants and excess salting regions (surface and intrusion into aquifers) superimposed on top. Note the close correlation of the pollutants and salting with stressed and impacted aquifers. Over pumping increases cross-contamination, reducing availability of clean water supplies or needing intensive cleanup and treatment where little to none was required before.

above, aquifers are potentially being contaminated by critical pollutants. So, waters that were previously clean are being contaminated, thereby either reducing our available supplies, or requiring costly cleanup, or extensive treatment. If new technologies can be developed that efficiently and robustly detect and remove contaminants from water, we can more efficiently use the water we have without as much loss and expensive treatment.

Similar to chemical contamination, waterborne pathogens can sicken significant numbers of people if introduced to water systems naturally or deliberately, or via cross-contamination with waste systems, which can render even major water supplies unusable. Moreover, treatment for pathogens can also inadvertently introduce toxic compounds to water supplies. Disinfection technologies are needed that effectively deactivates known and emerging pathogens without producing toxic substances. A key unsolved problem in need of research is the detection and removal of new and/or evolving infective viruses, and pathogens resistant to standard chemical treatment. If disinfection can be robustly done without producing toxic compounds, more water can be made available for use.

Current treatment technologies are typically not contaminant or pathogen specific, resulting in excessive and inefficient use of energy and chemicals during treatment. Treatment often removes benign and healthy constituents such as calcium and magnesium, and generates excessive residuals or sludge that require further processing and disposal. However, new materials and technologies can be developed that can selectively and affordably remove contaminants and pathogen, making waters safe without adding toxic treatment byproducts. A promising approach to decontaminating and disinfecting waters while saving water from transport, distribution, and treatment losses is by providing point-of-use, source, and discharge systems in a distributed infrastructure. Similar to new reuse and desalination technologies, these systems can range from single homes to large central systems. They can be added to existing systems, thereby reducing the need to completely

rebuild aging systems, saving total system costs. In addition, due to the high need around the world for point systems, a huge potential market for these technologies exists, so U.S. businesses and workers can also benefit from this research.

***Critical research needs include:*** (i) identification of classes of contaminants that need to be removed together and development of methods to detect them at the source and in distribution systems, (ii) development of standards and accepted modalities for determining infectivity of pathogens including viruses in water for near real-time detection, (iii) establishment of risk assessment and mitigation for treatment byproducts from current and new treatment methods, (iv) development of new selective contaminant removal and disinfection methods for priority and emerging pollutants, and (v) creation of new, robust, distributed point-treatment systems that do not create toxic treatment byproducts.

### Technology Diffusion

The United States has the scientific and engineering capabilities in our universities, government, and national laboratories to make great discoveries and find solutions to our problems. But unless these advances move from the laboratory to production, these innovations will not be used. Many novel approaches to problems may not take into consideration the costs of mass production or implementation. For new technologies to diffuse into the marketplace, they need to be independently benchmarked against current and competitive technologies, tested and verified. In addition, the total life cycle costs must be estimated and be shown to be favorable. Moreover, with respect to potable water systems, a history of performance efficacy and costs of installation and operation must be available for water managers to select with confidence one technology over another. Because of its oversight role with respect to drinking water, wastewater and environmental quality, and conducting water technology verification, it is

appropriate for the EPA to provide independent testing and verification of new technologies developed to increase water use efficiency and conservation.

Perhaps just as importantly, the funding of basic R&D by the Federal government for new innovative and cost effective technologies in water purification that can diffuse into the marketplace can help position U.S. companies to compete in the rapidly expanding worldwide markets for water technology. Many nations around the world (China, India, Singapore, Switzerland, and many within the EU) are pouring money and resources into developing new science and technologies for increasing water supplies and for new purification methods. While the U.S. still leads in basic science, we are falling behind in technology diffusion into the marketplace. The *WaterCAMPWS* Industrial Affiliates and the signers of the U.S. Strategic Water Initiative are anxious to develop competitive new products to solve the critical problems facing the U.S. and world. Large numbers of jobs can be created in the water sector in the U.S. if the technologies can be diffused into the U.S. technology and industrial sectors. If we do not develop and market these technologies here, we will lose our edge and likely have to pay companies from the other countries that are investing in new water technologies.

#### Current Recommendations for Enhancing Water Conservation

There are already recommendations pending before the new EPA Administrator that can enhance current water sustainability efforts without the need to revise existing Federal environmental statutes and regulations.

The National Advisory Council for Environmental Policy and Technology Committee issued two reports regarding Sustainable Water Infrastructure (July 2007 and March 2009) as well as extensive advice (May 2006, May 2007 and April 2008) on enhancing environmental technology

programs, including improved coordination and funding across Federal agencies, State permitting agencies, and even local watershed management organizations.

The National Academy of Sciences – National Research Council, and the Water Environment Federation recently submitted to EPA a research proposal entitled, “Sustaining the Nation’s Water Services,” to investigate technological opportunities, and the financial, regulatory, and societal issues associated with long-term water sustainability. The estimated cost of the full study is \$600,000, with \$50,000 to come from the Water Environment Federation.

#### Creation of a National Water Research and Development Advisory Committee

The United States Strategic Water Initiative (USSWI) that I mentioned earlier includes stakeholders from federal, state and municipal research programs, academia, water technology developers, and major water users such as the agriculture and energy sectors. The goals of USSWI are to:

- Increase basic science and technology research of water purification in academic and government research laboratories to enhance innovation and American competitiveness;
- Provide feedback from water associations, suppliers, users, practitioners, government officials, and the public on water purification needs, technologies, and product performance to water technology researchers;
- Provide a direct path for new ideas and technologies created in research laboratories to be evaluated, demonstrated, verified, and certified;
- Foster public and private investment in water purification research, and accelerate the diffusion of technologies (implementation, commercialization, and adoption) that emerge from such research;

- Establish a cooperative research agenda including a prioritized list of gaps, needs, and opportunities in water science and technology.

Because a substantial water research and development effort already exists outside the federal agencies, we believe that input from this external community is essential to the successful development and implementation new water technologies. We therefore recommend that a standing National Water Research and Development Advisory Committee be established under the Federal Advisory Committee Act, to provide advice and counsel to the EPA Assistant Administrator for Research and Development, and to information on extra-mural water research and development activities to the Assistant Administrator.

#### National Interdisciplinary Water Research Centers

Finally, we strongly support the creation of national interdisciplinary research Centers with participation from U.S. universities, water associations and research foundations, and the private sector including technology companies, innovators, and finance, to accelerate the diffusion of new science and technologies from Federal, State, and local research laboratories, as well as university and foundation funded research, into the marketplace. The Centers should be independently managed with governing boards that include the participating stakeholders along with relevant agencies such as the EPA.

To create these new national research Centers additional funding will be needed. Other nations establishing such publicly-funded Centers, such as two in Singapore and one in the Netherlands, are funding them at \$30 to \$60 million per year per Center for periods of 5 to 10 years, with similar investments by the private sector. A greater amount is being expended in Switzerland (~\$100 million/year) to develop new technologies to reduce water usage in the domestic and energy sectors. These efforts are also attracting private sector investment. For

example, GE announced on March 19 that it will invest \$100 million to establish a water technology research center at the National University of Singapore. It is likely that a greater level of funding will be needed to solve the larger problems the U.S. faces over several sectors and over disparate geographic regions. Basic research in water science and technology in the United States is funded at about \$12 million/year at the NSF, EPA, and DoE. To rapidly increase water R&D, we recommend that Congress consider an increase in federal funding to a level of \$100 million per annum beginning in FY 2010 with annual increases of 5% through 2019.

In closing, on behalf of the academic research community and the water technology sector commend the Committee for recognizing the need for coordination across the breadth of federal agencies conducting water-related research. For our part, we stand committed to assisting the EPA by expanding our existing partnership and in coordinating our own work in furtherance of the Agency's research agenda. It is our belief that R&D is essential for the United States to succeed in increasing water use efficiency and better conservation, which is essential to our future.

Thank you, Mr. Chairman and members of the Subcommittee for this opportunity to provide this testimony. I would be happy to answer any questions you may have.